

Rock Lake Stabilization

Soil Bioengineering Research Project – Phase 1
Hwy. #60, Rock Lake, Algonquin Park



Technical Report Documentation Page

Rock Lake Stabilization Soil Bioengineering Research Project - Phase 1 Hwy. #60, Rock Lake, Algonquin Park

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Abstract:	Soil bioengineering, as demonstrated in the Rock Lake Stabilization Soil Bioengineering Research Project, is a valuable land stabilization system for use in highway construction and rehabilitation: - where aesthetics or habitat rehabilitation are important factors; - where machinery and construction supplies are difficult to obtain and where labour is plentiful; - where small failures require quick repair by field crews; - and in conjunction with other techniques to increase strength and longevity. Proper site investigation and analysis, construction planning and installation are essential to the long-term success of the installation and are discussed in detail in the report, both generally and specific to the Rock Lake test site. Although our knowledge and expectations of soil bioengineering in Ontario are far from complete, the report concludes that the techniques studied can make a valuable contribution to stabilization efforts associated with Ontario's highways.
Comments:	Monitoring of the site will continue in 1989.
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EXECUTIVE SUMMARY

This report summarizes the objectives of the research project in soil bioengineering by the Ministry of Transportation and Communications (M.T.O.) at Rock Lake in the Bancroft District, Ontario, Canada. It reviews the original site conditions, the techniques employed, the problems encountered on site and the results of the project. It concludes that the soil bioengineering has effectively stabilized the slope and recommends the following:

1. Selected soil bioengineering techniques should be included in the Ministry's soil erosion control solutions and Ministry staff should be trained in the use of generic soil bioengineering systems that could be used in a repeated fashion on generic problems.
2. Soil bioengineering should be continued on the site under normal project conditions.
3. Monitoring of the site should continue for the next three years.

INTRODUCTION

The purpose of this research project was to investigate the application of soil bioengineering/biotechnical construction techniques for slope stabilization and revegetation. Specifically, this research was conducted to test the effectiveness of these techniques in solving problems typically encountered by M.T.O.

Generally stated, the objectives of this study were:

1. To learn some of the techniques and processes used in soil bioengineering installation and their associated costs.
2. To evaluate the effectiveness of soil bioengineering in slope stabilization in Ontario.
3. To identify and document effective techniques and materials for use by M.T.O.

At the outset, it was presumed that these techniques would prove useful for highway slope stabilization for the following reasons:

1. The results included natural recolonization of the slope making it valuable where aesthetic or environmental considerations were important.
2. Installations required no topsoil, special soil preparation, fertilizer or routine maintenance.
3. Installations were labour intensive but were executed at a time of year when unemployment was high, labour subsidies were common, and most similar construction was intermittent.
4. Solutions should be less costly than comparable "hard" solutions.

5. The lack of machinery and supplies required should allow for use in remote/inaccessable areas.
6. Slope stabilization could be executed without disturbing existing vegetation or other desirable features on a slope.

These contentions plus others identified during the investigation were monitored and were discussed in this report.

The site selected for a soil bioengineering solution is a cut slope on Hwy. #60 within Algonquin Park. This site was chosen for a variety of reasons, listed below.

1. The District (No. 10 - Bancroft) showed considerable interest in soil bioengineering and had staff with some knowledge of the techniques used.
2. Traditional techniques, eg. seeding, had not affected the stabilization of the slope to date.
3. The site had a high profile, within Algonquin Provincial Park.
4. A natural solution was desirable, if not mandatory, within the park.
5. Many similar sites existed within the District where these techniques could be applied in the future.

CHRONOLOGY

During July of 1985 the project was started with a preliminary site investigation and collection of historical, geomorphological, physiographic, climatological, botanical and historical information. The site was photographed and reviewed by all concerned.

Preliminary findings were presented in August, 1985, illustrated on two drawings showing the existing site, the various observed conditions and the apparent types of erosive forces encountered. It was decided to proceed with Phase Two.

In October of 1985, the proposed design solution was presented and implementation discussed. Approval was given to proceed the following spring.

The spring of 1986 was very early and warm, causing the project starting date to be advanced twice from our original estimate.

Construction began on Tuesday, April 15, with presentations to the complete crew of twenty outlining the basic principles and techniques to be applied. Following this, the entire crew proceeded to harvest/cut the required plant material. Construction on the slope proper was started on Thursday, April 17. The crew worked through to Friday, May 2, 1986, losing 1 day to rain.

By Friday, April 25, the plant material was in full flower and it was recommended that soil bioengineering work be discontinued. However, the Ministry decided to continue through the last week to test the effect of the

advancing season on the success of plant material, to clean up the site and to finish the planting of the rooted stock. The crew was reduced in size to 16 for the final week through attrition.

The site was observed monthly throughout the summer of 1986 with a final assessment in August. The weather at the site was unusual, beginning with an early, warm spring, followed by a late frost at the end of June, greater than average rainfall throughout the summer, an early frost at the beginning of September, and an extraordinarily wet fall.

THE SITE

The demonstration site is located on Highway #60 right-of-way within Algonquin Provincial Park. The slope is located on the south side of the highway, just under 1 km west of the Rock Lake Campground Road and faces north west. It is a large cut section, measuring approximately 230m in length, with face elevation of over 35m at the centre.

The site is situated within the Grenville Province of the late Precambrian Canadian Shield, within the Algonquin Dome of the Laurentian Highlands. The overburden consists of a clay silt combined with a boulder till. The cut has been made through the lower part of a large hill which rises to the south. Solid bedrock is visible at the top of the hill but is not in evidence on the north face at all. The land drops dramatically to the west to a low, wet area (see Fig.1).

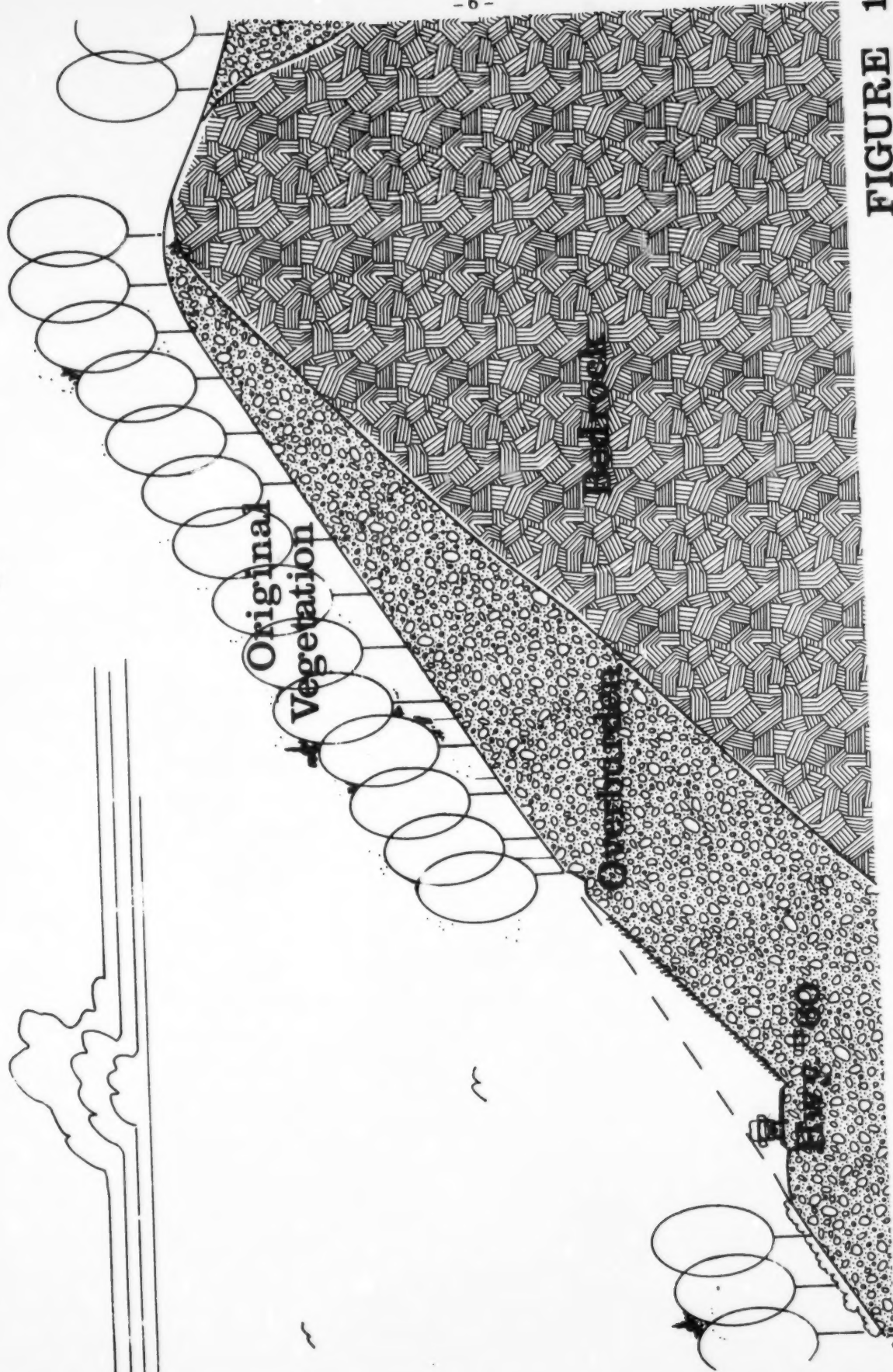


FIGURE 1

HWY.#60 ROCK LAKE

Slope Stabilization

The highway at the site slopes down a long, even grade to the west. An asphalt paved ditch intercepts water at the edge of the pavement and directs it into a double catch basin within the cut section and from there, across the road to a creek beyond the right-of-way on the north side. Some permanent runoff seeps down the ditch from above the slope to this point and enters the catch basin as well. Past the catch basin, surface runoff flows through a deep ditch off the site to the west. An interceptor ditch is located at the top of the cut slope with a riprap outlet down the face near the centre of the cut and discharges into the ditch.

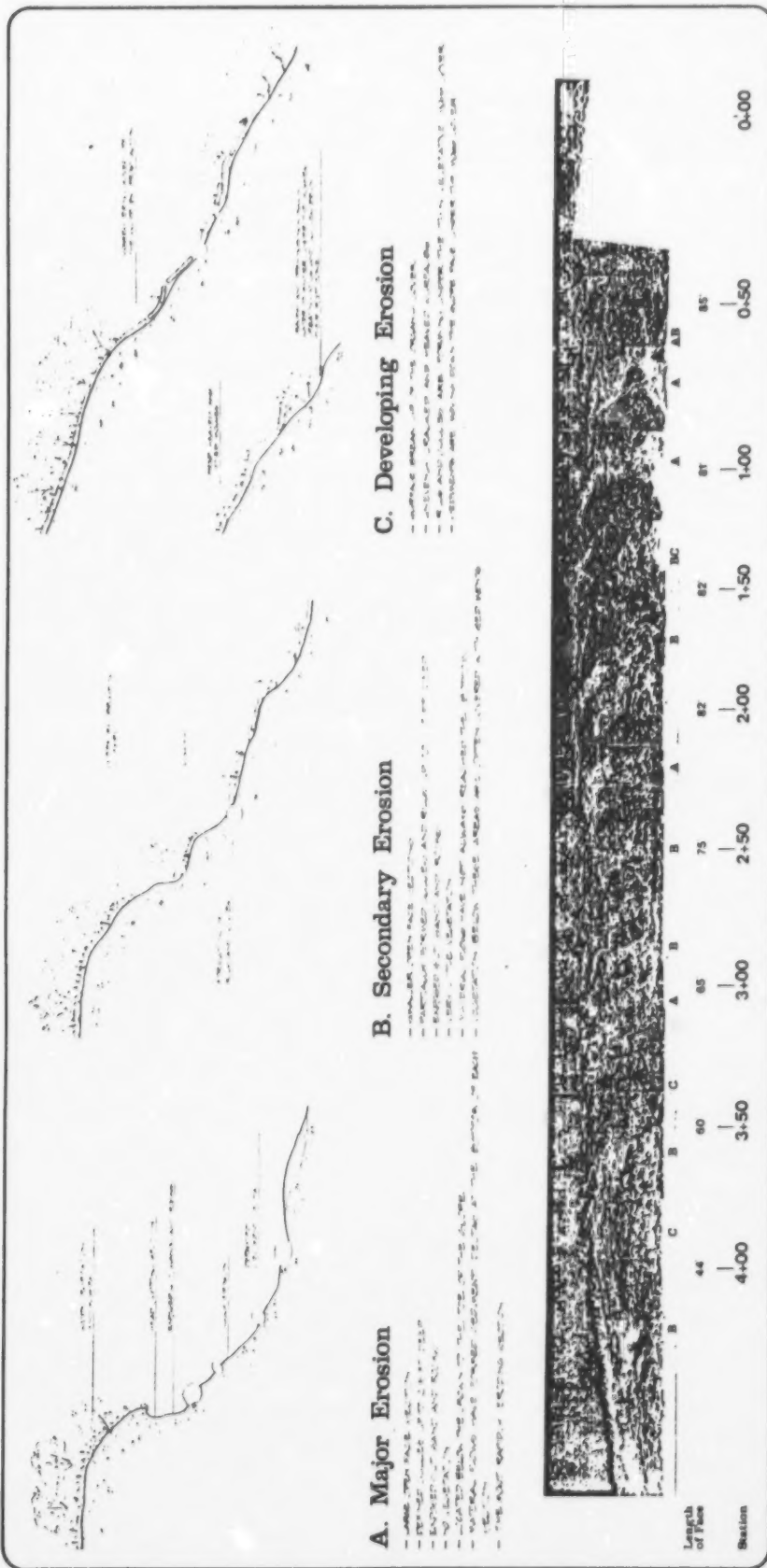
According to M.T.O. records, the cut slope was a result of reconstruction of the highway in 1967. The face had a slope which exceeded 2:1 and the soil a pH of 5.27. It was seeded with a crown vetch in 1969 and an excellent catch was reported with vigorous rooting. The slope was reseeded at a later date with some erosion mentioned in 1970 reports. In 1971, the interceptor ditch was constructed to eliminate surface discharge onto the slope face which was thought to be the cause of the instability. By 1974, the crown vetch had deteriorated and mosses and alpine plants became the primary ground cover with some woody species invading. From 1974 to 1983, some natural regeneration of native woody vegetation became established. In 1983-84, the entire slope was cleared by hand, removing all existing woody vegetation. Spray to control brush eliminated woody deciduous regrowth on the lower 7m of the slope. Above this, some suckering and regrowth had taken place.

As of July, 1985 on the eastern half of the slope, the predominant groundcover was moss with some associated herbaceous growth and remnant crown vetch and grass individuals. Some regrowth of woody vegetation, both suckers and seedlings, have established themselves in islands above the spray lines. Roughly 50% of the surface was barren and susceptible to surface erosion with open patches of soil evident almost everywhere. Five major gullies dissected the site with many large rocks at the surface. There were two slumps at the toe of the slope as well as some minor silt buildup within the ditch.

ANALYSIS

Although a substantial area of the slope surface was bare, the actual amount of soil moving off the surface was relatively small and apparently moving at a fairly slow, consistent rate. This, plus the presence of the interceptor ditch, the slumps, and the head cutting in the gullies indicated a problem of excess soil moisture (probably fed by gravity from the large hill above) as opposed to surface water erosion. This was further substantiated by the relatively slow, steady break-up and erosion of the surface, even though the face was at times covered by well-rooted vegetation.

The erosion of the slope moved gradually through the three stages depicted on Fig. 2, Site Analysis.



Soil Bioengineering Research Project
 Hwy. #60 Rock Lake-Algonquin Park
 Ministry of Transportation and Communications, Ontario

Soil Bioengineering Corporation
 Harrington and Boyle Ltd.

Figure 2
SB-2

First, the thin moss layer was lifted and fractured by frost action in the saturated soil. Cracks allowed penetration of surface water to the moist soils. The water found its way along cracks or under the moss cover's shallow anchoring zone, dislocating sediments as it moved (see Section C, Fig. 2).

The moss cover then began to deteriorate as it was undermined. Open areas began to form and expand and small gullies became established. Silt deposits covered the vegetation below these openings or gullies, and head cutting extended them up the slope.

Finally, full gullies were formed which reached the toe of the slope and silt was deposited in the ditch. Open gullies were void of vegetation and subject to accelerated erosion by wind and water movement. Gullies continued to expand laterally and uphill through the head cutting process.

This process was slow but showed no sign of reversing and stabilizing itself without some form of intervention. The soil bioengineering solution, if it was to be successful, had to accomplish the following:

1. Moderate the excessive freeze/thaw extremes on the slope.
2. De-water the upper soil layers.
3. Anchor the surface securely and deeply into the subsoil.
4. Control surface water and sediment movement.
5. Begin to rebuild and improve the topsoil and prepare the site for the invasion of the surrounding plant materials, thus diversifying the vegetative cover.

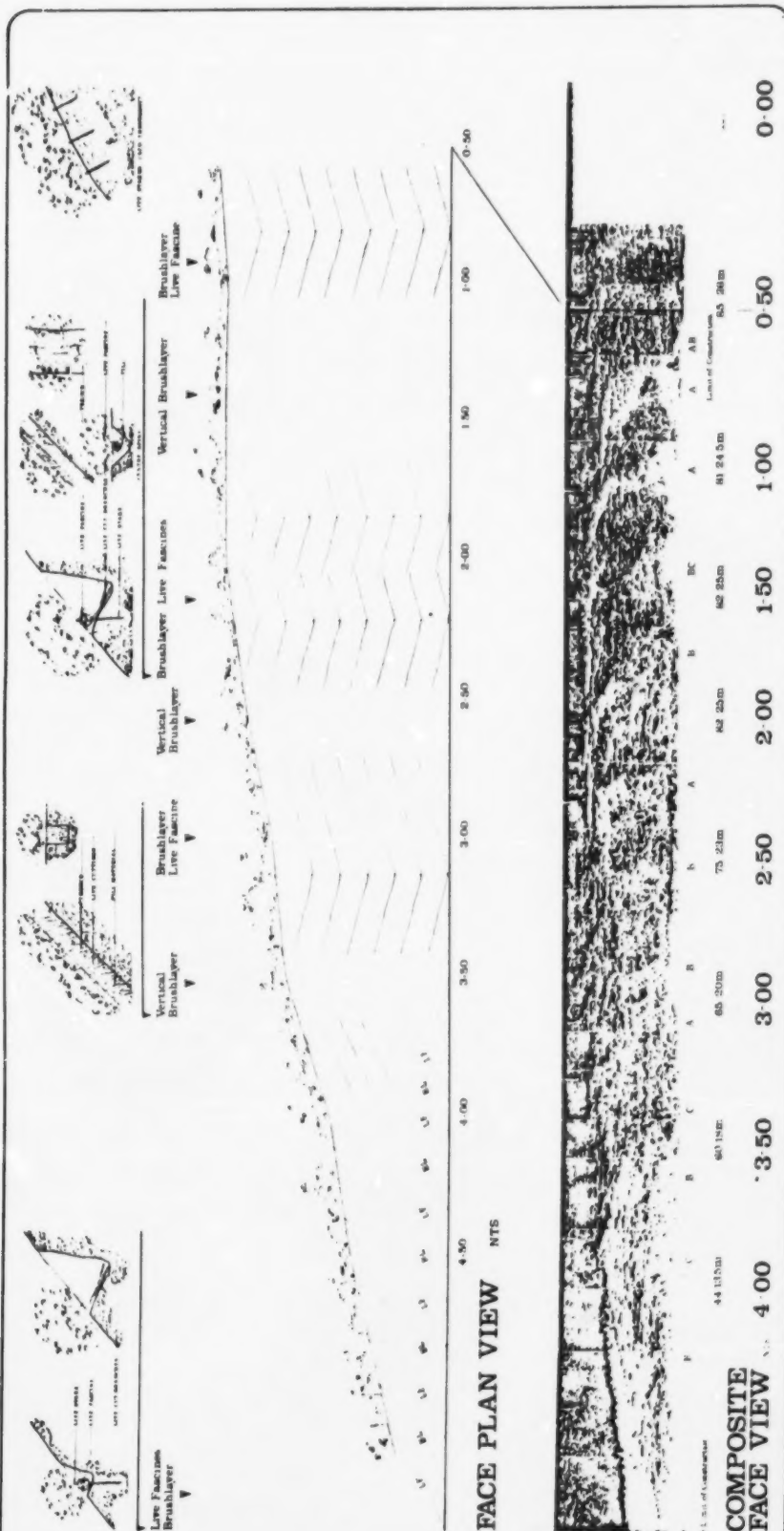
RECOMMENDED SOIL BIOENGINEERING SOLUTION

Three distinct soil bioengineering techniques were employed in the proposed solution as indicated on Fig.3. These were: alternating live fascines and brushlayers, vertical brushlayers, and brushlayers with live fascines. Live staking was used throughout the project. These were all be laid out on site attempting to minimize the disruption of any existing land and vegetation and to respond to exact site conditions. They may, therefore, not have conformed exactly to the prepared drawing. While the primary reason for using 5 techniques was to respond to the various site conditions as outlined earlier, it also afforded us the opportunity of evaluating a number of techniques.

THE LIVE SYSTEMS - SPECIFICATIONS

The live systems recommended for the project site were designed in specific combinations to best repair, protect, and to cause the site to become as self-supporting and natural as possible. The following specifications were prepared by the Soil Bioengineering Corporation to guide the construction process.

Live Stakes...see figure 4. Live stakes are cut from rootable plant stock. They are carefully tamped into the ground of the slope where they are expected to take root and leaf. After they have developed roots, they add deeper consolidating and reinforcing capabilities to the system. They are also able to draw moisture out of the soil through transpiration. These units shall be used in combination with other living structures to join systems together, to add strength to potentially weak areas and also to strengthen existing vegetative areas on the slope face.



Soil Bioengineering Research Project

Hwy. #60 Rock Lake - Algonquin Park

Ministry of Transportation and Communications, Ontario

Soil Bioremediation Corporation

Harrington and Hovle Ltd

Construction Details

Legend
 Amount of loss
 1-4 5-9 10-20 21-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100

Frequency
 0-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100

Frequency Type
 A B C

Figure 3

SB-3

Rooted Material...Nursery grown rooted cuttings or seedlings planted on the slope between the other systems. Their purpose is to increase the diversity of plant species on the site beyond those which can be propagated successfully through live cuttings. Species are selected to attract wildlife which will in turn introduce more diversity of plant species on the site and encourage natural invasion.

Vertical Brushlayer...see figure 5. In this system, live cuttings are placed in prepared trenches on the slope face. Branches of live, rootable, biotechnically capable plants are placed vertically into the slope. This system is capable of acting as a sediment barrier to soils moving down the slope. This system normally functions singularly.

Brushlayer/Live Fascine...see figure 6. This system is developed with two major units. Bundles of live plant cutting material are bound together to form sausage-like structures. Initially these serve as "pole drains" to direct waters across the slope. A combined live system is developed through the placement of live cuttings on prepared terraces in the slope sections, forming a brushlayer. This live system adds immediate soil reinforcement. This reinforcement will continue to increase as the roots develop and consolidate the soil. The exposed brushy portions of the new brushlayers also function immediately by forming sediment barriers across the slope. This controls surface runoff, preventing the formation of gullies. These combined live structures will take root along their full length and pump water out of the slope through transpiration.

Angled Live Fascine/Brushlayer...see figure 7. Bundles of live plant cutting material are bound together to form sausage-like structures. Initially these serve as "pole drains" to carry waters directly down the slope. A double brushlayer system is placed on the sides of the prepared trench. The exposed brushy portions of the new brushlayers function immediately by forming sediment barriers on the slope. This controls surface runoff and prevents the formation of a wider gully. These live structures will take root along their full length and pump water out of the slope through transpiration. These systems are normally connected to Brushlayer/Live Fascine units.

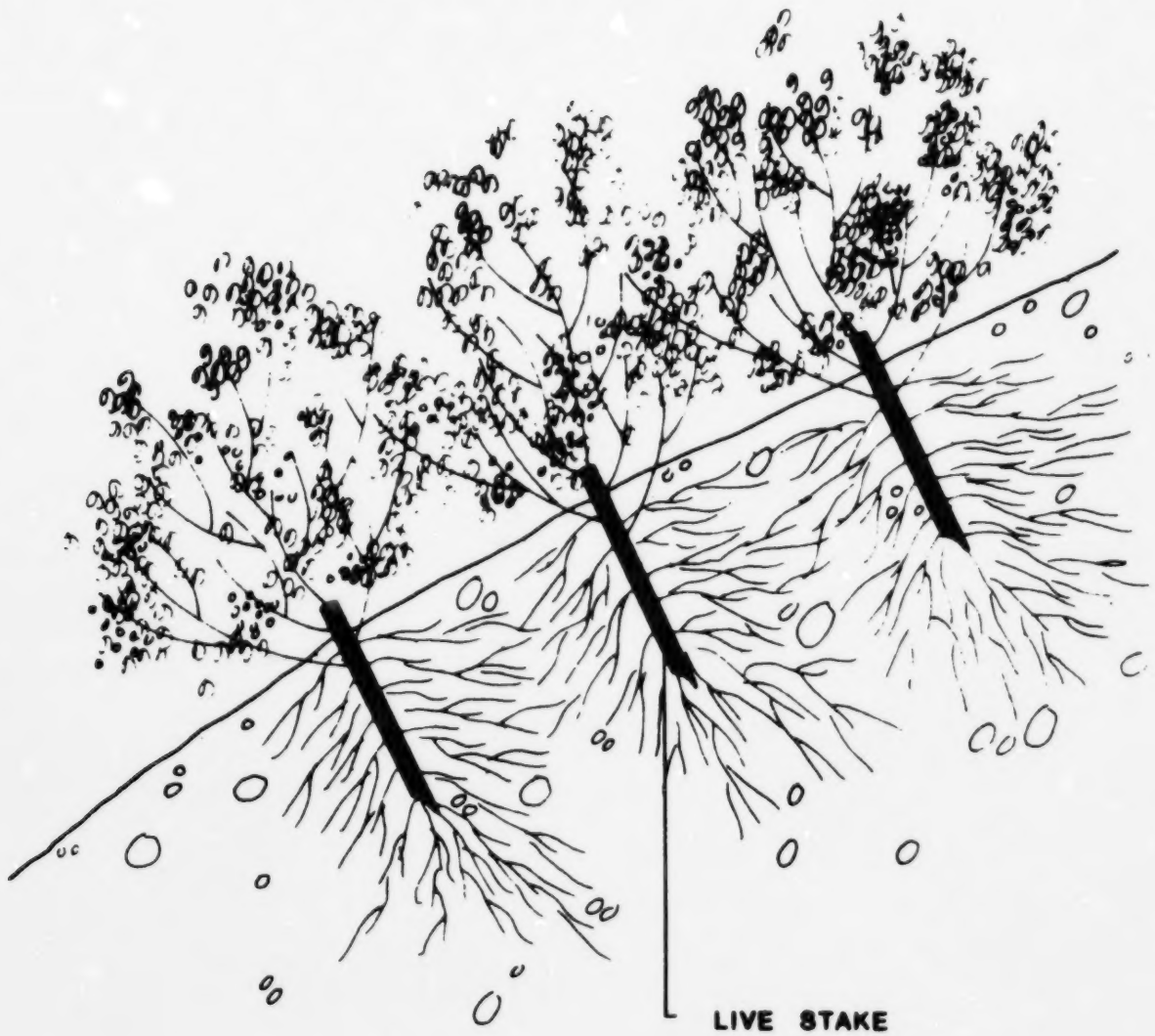
Hedgelaye... Constructed similar to brushlayer with rooted cuttings placed on top of the live cuttings. This system is used to extend the construction season beyond the time when higher results can be obtained from live cutting material or when sufficient acceptable cuttings are not available. It can also be used to increase plant diversity within the individual system.

FIGURES

The following pages of figure drawings for each of the proposed soil bioengineering structures are as follows:

- Fig. 4. Live Stake
- Fig. 5. Vertical Brushlayer
- Fig. 6. Brushlayer/Live Fascine
- Fig. 7. Angled Live Fascine/Brushlayer

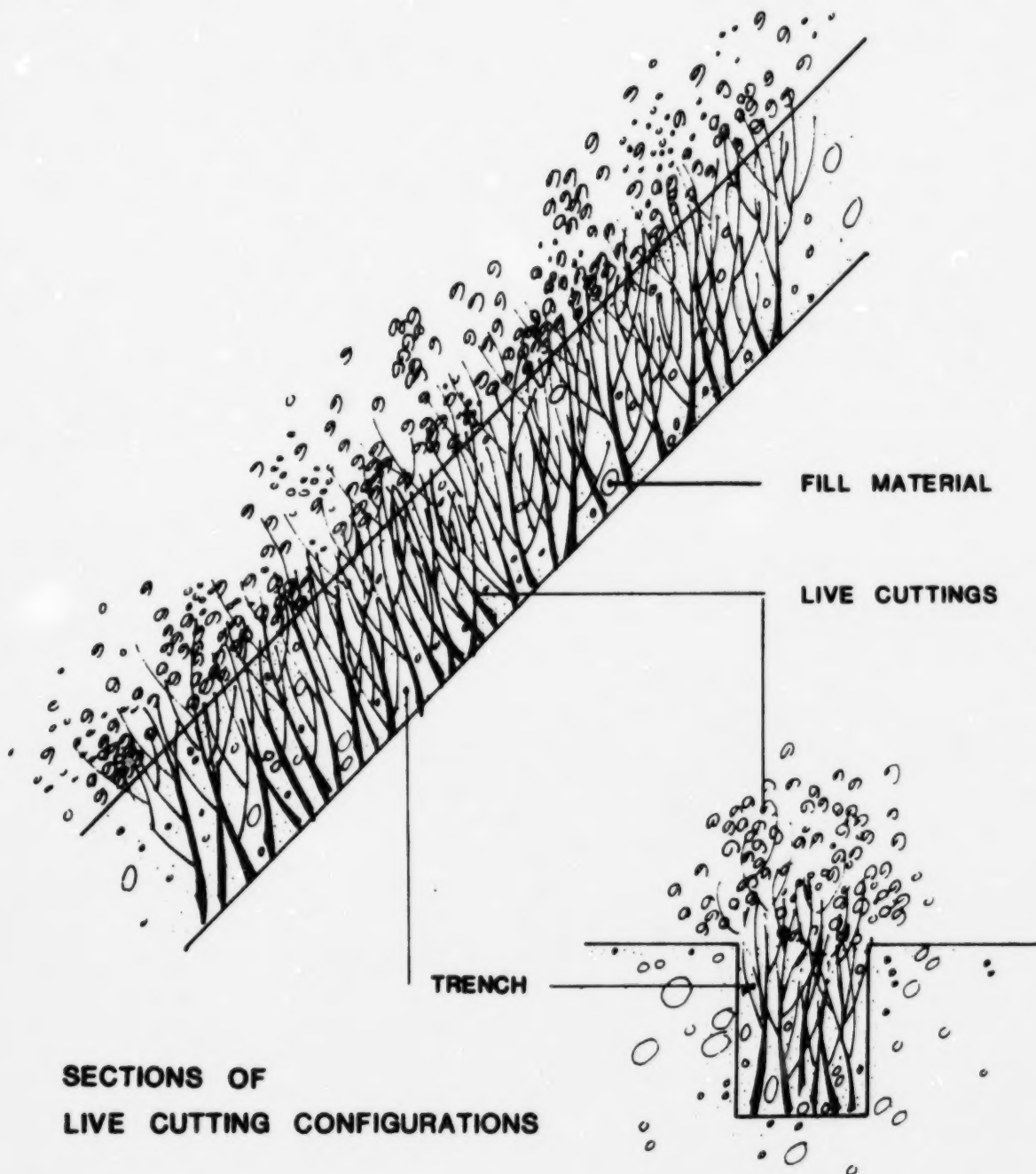
LIVE STAKE



NTS

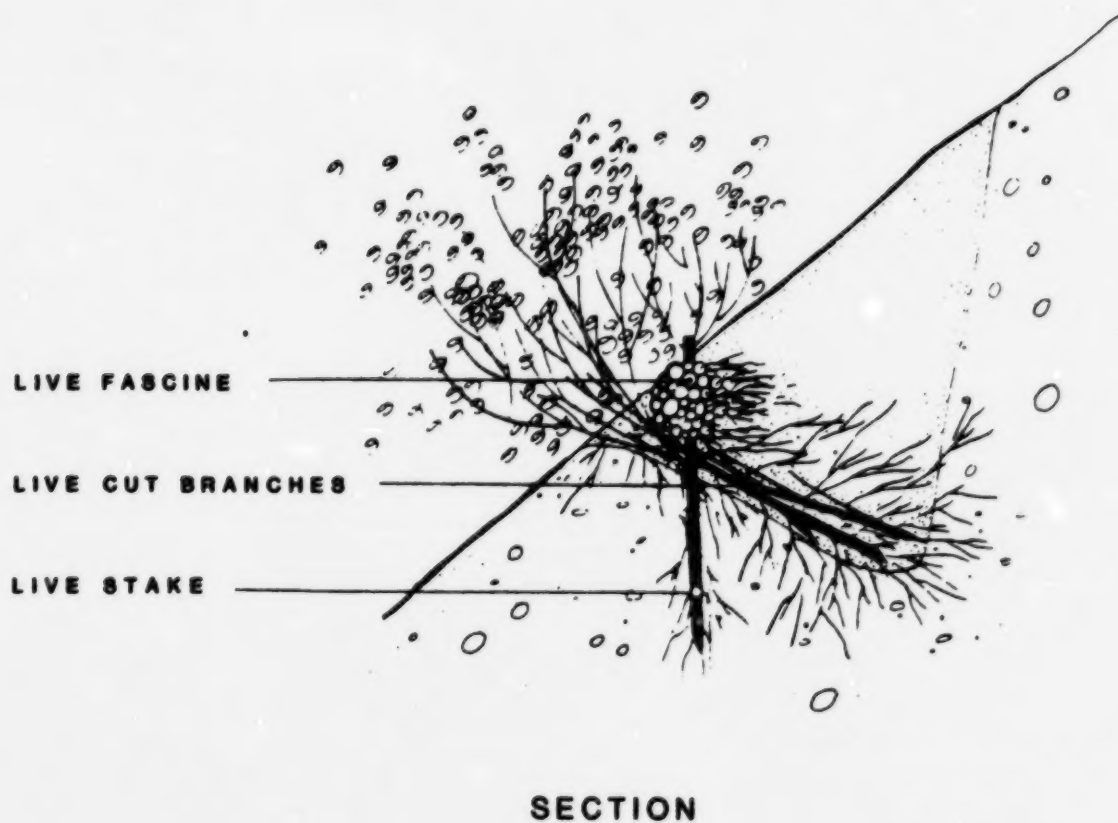
FIGURE 4

VERTICAL BRUSHLAYER



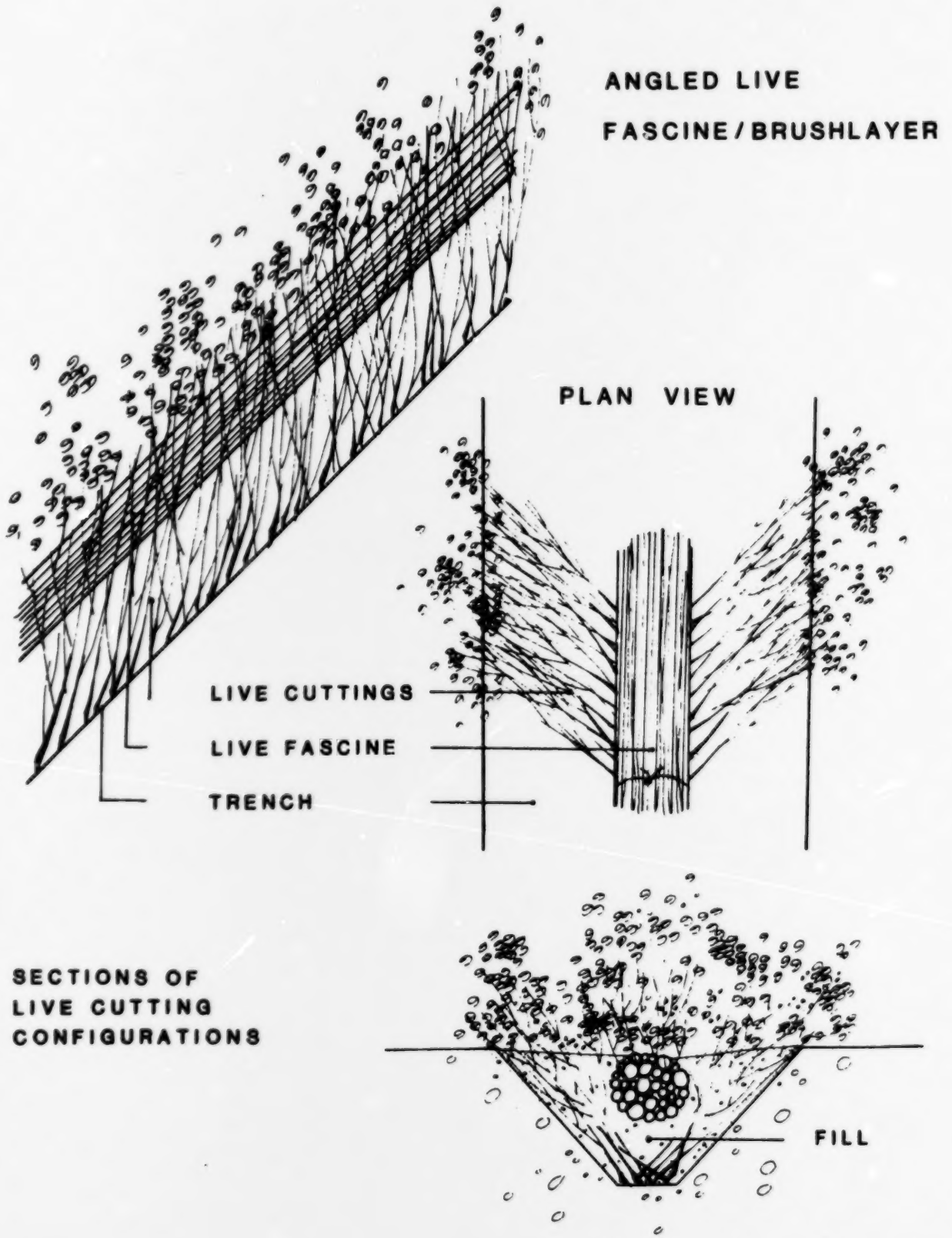
SECTIONS OF
LIVE CUTTING CONFIGURATIONS

BRUSHLAYER / LIVE FASCINE



NTS

FIGURE 6



MATERIAL SPECIFICATIONS

Soft Materials

Live Stake Construction...see figure 4. The live branches or sticks, which shall be trimmed and cut to length for this construction technique, shall be 50 to 60 cm long and 2 to 4 cm in trunk diameter. They shall be cut flat on top and at an angle on the bottom and for easy tamping into the ground. All side branches shall be removed.

Vertical Brushlayer...see figure 5. The live cut branches that are to be placed in the prepared trench shall be 70 to 80 cm long with a maximum basal cut trunk end diameter of 4 cm. All side branches shall be retained as part of this construction. Soft, brushy material functions the best.

Brushlayer/Live Fascine...see figure 6. The live branches to be used for the construction of the live fascine shall be made from soft branching material and shall have all the growing tips lying in the same direction. The built wired or string tied live fascine unit shall be approximately 15 to 21 cm in diameter. The live fascine shall be wired or string tied together every 30 cm. Live cut branches to be placed in the slope as brushlayers on the prepared terrace shall be 70 to 100 cm long, as required. The basal cut end of the branches shall have a maximum trunk diameter of 4 cm. The attached branches shall be retained in both live units and shall be used as part of the live construction.

Angled Live Fascine/Brushlayer...see figure 7. The live branches to be used for the construction of the live fascine shall be made from soft branching material and shall have all the growing tips lying in the same direction. The built wired or string tied live fascine shall be approximately 15 to 20 cm in diameter. The live fascine shall be wired or string tied together every 30 cm. Live cut branches to be placed in the trench on either side of the live fascine shall be 80 to 90 cm long, as required. The basal cut end of the branches shall have a maximum trunk diameter of 4 cm. The attached side branches shall be retained and shall be used as part of both live units for this construction.

Hard Materials

Suitable Fill Material: Vertical brushlayers, brushlayer/live fascines and angled live fascine/brushlayers shall be filled with approved material. The fill shall be pervious backfill material, presently available on the site. Oversaturated soils or those which would adversely affect plant growth may not be used.

Wire: Wire used for the purpose of tying the live fascine units together shall be 20 gauge steel wire, i.e., electrical fencing wire. Bailing twine may also be used as an alternative to securing the live fascine bundles.

INSTALLATION SPECIFICATIONS

Soil bioengineering installation shall be combined and accomplished at the same time as excavation and backfill work is being performed. It is intended that each live construction be smoothly and securely transitioned into adjacent live constructions. Each land section requires skillful observations to ensure that the correct combination and system placement is performed, to best suit the land repair needs. In this area of the work, it is an art (experience) as well as a science. Soil bioengineering installations require careful supervision at each performed level of live structure building. Existing plans or cross sections may not be available for these sites; therefore, proposed system installations may be changed on site during construction to best accommodate the site conditions.

Live Stake Installation...see figure 4. Live staking is to be used on the slope and banks to connect the live systems and to serve as adjuncts to existing vegetative sections.

Placement: The live stakes are tamped directly into the ground using dead blow hammers designed to deliver the force of the hammer while minimizing the impact of the equipment on the material. Finished stakes should protrude approximately 7 cm above the ground. They should be placed at a ninety degree angle to the slope. In existing vegetative sections, these depths may vary.

Density: The stakes shall be placed 50 to 100cm on center. Exact placement for each section shall be determined on site. Live stakes shall not be placed closer than 50cm apart.

Rooted Material Installation...Rooted material is to be used on the slope to provide diversity of cover and seed sources for colonization of the slope with diverse vegetation and to increase the variety of rooting systems which work to stabilize the slope.

Placement: Rooted cuttings shall be planted in shallow excavations such that their root systems maintain their natural orientation. Plants should be healed in and kept moist and cool until planted. Planting shall be at the same time as the holes are dug with the soil firmed around the roots to eliminate air pockets.

Density: Rooted cuttings shall be planted a maximum of 2m apart. Exact placement for each section shall be determined on site.

Vertical Brushlayer Installation...see figure 5. This live construction may be started at any point in the excavation section, but it is generally easier when started at the bottom. It should be accomplished at the same time as the conventional work is occurring.

Procedure: A trench is dug 50 to 60 cm deep and 20 to 30 cm wide. This excavation is made vertically up the face of the slope and over the crown.

Vertical Brushlayer Installation continued

Placement: The live cut branches shall be placed into the prepared trench. These shall be placed vertically (that is, at a forty-five degree angle to the trench). The live branches shall be placed with the growing tips pointing outward. They should protrude approximately 15 cm out of the trench.

Density: The density of the branches to be placed in the trench shall be approximately 40 to 50 brushy stems per lineal metre.

System Backfill: The earth backfill shall be placed on either side of the placed live branches. It shall be foot compacted to ensure that air spaces around the branches are filled with soil.

Final Appearance: The brushlayer shall be straight up and down. The brushlayer itself shall be 15 to 20 cm wide.

Brushlayer/Live Fascine Installation...see figure 6. This installation shall be performed on the site on areas joining the face slope sections to the central angled live fascine/brushlayer units. They shall be located at a 15 to 20 degree angle to the slope. Exact placement shall be determined on site.

Procedure: A terrace is dug 70 cm wide. The back of the terrace shall be 15 cm deeper than the front edge.

Brushlayer/Live Fascine Installation continued

Placement: These units shall be placed into prepared terraces that have been cut out of the slope. The live brushy cuttings shall be placed on the terrace first. Then the live fascine shall be placed and staked in place with live stakes. The live fascine bundle units shall be continuous. The live fascine shall be placed on the outer edge of the terrace so as to allow for almost all of it to be covered. The brushlayer should protrude out of the trench 15 to 20 cm.

Density: The density of the brushlayered branches to be placed on the prepared terrace shall be approximately 15 to 20 branches per lineal metre. One single live fascine is placed on each branch or brushlayer.

System Backfill: The earth backfill lifts that are placed on the live branches shall be a maximum of 10 cm at a time and shall be foot compacted to ensure that the air spaces around the branches are filled with soil.

Final Appearance: The brush shall be protruding with an upward angle in the finished product. The live fascine bundles shall be slightly visible when backfill operations are completed.

Angled Live Fascine/Brushlayer Installation...see figure 7. Live construction shall be started at the lowest point in the cut section and shall be constructed at the same time as the conventional construction is occurring. This installation shall be connected at various points along the sides by the brushlayer/live fascine units.

Procedure: The trench shall be excavated approximately 50 to 70 cm deep with approximate forty-five degree angle sides. The trench shall be approximately 50 to 60 cm deep. The trench shall be dug up the face of the slope. It shall not be located above any adjoining brushlayer/live fascine construction unit.

Placement: The live cut branches, forming the brushlayers, shall be placed on both sides of the trench, against the sides. The growing tips shall be towards the outside and should protrude above the trench approximately 15 cm. The live fascine bundle shall then be placed in the center of the two brushlayer cuttings. This unit should be staked in the centre, through the bundle at an angle on either side of the unit.

Density: The density of the branches to be placed in the trench shall be approximately 10 to 15 branches per lineal metre on each side.

System Backfill: The earth backfill lifts that are placed on the live branches and around the live fascine bundle shall be a maximum of 10 cm at a time and shall be foot compacted to ensure that the air spaces around the branches are filled with soil. Soil shall be placed on top of the brushlayers and foot compacted prior to the placement of the live fascine bundle. Then the backfill shall be completed and foot compacted.

Angled Live Fascine/Brushlayer Installation continued

Final Appearance: The brush shall protrude out of both sides of the trench and the live fascine bundle shall be slightly visible. The live stakes used to secure the bundle shall protrude approximately 2.5 cm above the bundle.

Hedgelay Installation... This system is used to replace brushlayer installation when the live cuttings are not expected to grow. This could be because of "dead" material or because of an advancing season. This work is generally done after all other work has been completed or when making repairs after the dormant season.

Procedure: A terrace is dug along the slope where required, 70 cm wide and 15 cm deeper than the front edge.

Placement: Brushy cuttings shall be placed on the terrace first and covered with soil and compacted such that no air pockets remain. The brushy material shall be 10 to 15 cm thick and protrude 15 cm out from the soil when completed. Rooted cuttings are then laid on top of the brushy material. The root system of the cuttings should be spread out on top of the brushy cuttings.

Density: The density of branches to be placed in the trench shall be 40 to 50 brushy stems per lineal metre with 3 to 5 five rooted cuttings per lineal metre.

Hedgelay Installation continued

System Backfill: The earth backfill shall be placed on either side of the branches and compacted to ensure that air spaces around the branches are filled with soil.

COMBINED SYSTEMS

Live structures develop over time and become stronger. Resistance to erosion on the site is expected to reduce in time due to the rooting function of the live plants. They are expected to increase the shear strength in the soils. The intermingled, lateral roots of plants will tend to bind the soil together into a monolithic mass. On the slope, the root system, ie., the anchor and feeder roots, should be capable of penetrating through the soil mantle into the strata below, thus anchoring the soil to the slope and increasing resistance to moving.

It should be noted that any of these may be modified by site conditions at the time of installation. An attempt should also be made to concentrate any shrubby material at the lower part of the slope for reasons of highway safety and to reduce the necessity of maintenance cutting.

MATERIAL

Plant material came from four sources.

1. Live Poplar and Willow cuttings from the Whitney and Madawaska area.
2. Various cuttings randomly harvested from existing cuts within the park, ie., hydro.
3. Random selected material from along the edge of the highway right-of-way.
4. Rooted seedlings of Red Osier Dogwood and High Bush Cranberry.

Of these, the Whitney and Madawaska areas provided by far the largest percentage of biotechnically usable material. Random cuttings were used as filler or dead brush and, combined with live material and selected material from roadside, were used for special needs or finishing. Rooted seedlings were added to increase species variety and shrubby material content.

Three species made up the live material to be used. These were willow, poplar and dogwood. Ideally, these were combined with willow species as the largest proportional component. These are vigorous rooting species. Birch, Striped Maple and Tamarak were added to provide variety in rooting structure and branching. Approximately 20 acres of vegetation in various locations were needed to be cut to provide the required material.

INSTALLATION

The installation began on Tuesday, April 15, 1986 with a 1 hour slide presentation and lecture to the crew outlining the techniques to be used for cutting, transportation, preparation and installation of the living plant material with a question period following. A presentation was also made by MNR concerning safety and fire prevention in forested areas. The crew then went to the cutting site and cut material for the remainder of that day and the following day. Installation began on site on Thursday with half of the crew (10 people) installing live fascines and brushlayers and the other half cutting. Friday, the entire crew worked at installation to avoid storing material cut Friday until Monday. The pattern of the crew cutting Monday, dividing Tuesday, Wednesday and Thursday between cutting and installation, and installing on Friday was followed generally throughout the project.

PRINCIPLES

During the course of the project the following principles emerged as important for soil bioengineering installation.

The trench should be opened a minimum amount of time before backfilling.

Cut plant material should not remain exposed for longer than 1 day before placing in water.

Cut material should not be stored in water longer than 2 days before installing.

Plant material should remain with the original top of segment in the uphill position if it is expected to grow.

Plants expected to grow should maintain maximum contact with the soil with no air pockets to dry out soil.

Mixtures of materials are important. Mixtures should contain a minimum of 50% willow species to encourage the rooting of all material.

Ragged edges on material, ie., from chain saw cuts, do not hurt. Rough handling from stepping on materials during installation does no harm.

Scarring live stakes during sharpening is unacceptable as is excessive damage (peeling or bruised bark) through tamping into soil.

DISCUSSION

Installation

As mentioned earlier, the material used for this installation came from a variety of sites. The ideal site should be close to the installation site and consist of reasonably dense stands of young, usable material. A variety of material in the same location is also desirable. In fact, only one site met this criteria, that being on the dump road just north of the town of Whitney. The remaining sites were widely dispersed and tended to have a single, dominant species present. Some were far from the installation site.

Harvesting Site #1, shown on Figure 8, is an M.N.R. plantation of red and white pine with a good deal of poplar rejuvenation between the plantation trees. Material was harvested from this area with the dual objective of securing a supply of poplar (mostly Trembling Aspen) for use in soil bioengineering while at the same time, improving the plantation by reducing poplar competition. The fire/access roads were used to gain access to the interior and the entire crew was trained in harvesting techniques at this site. This site was very productive, but yielded only poplar with no other material to be mixed with it.

Harvesting Site #2, Figure 8, was the ski hill at Madawaska. This site produced good quantities of willow and dogwood from the verges of the runs and staging areas while also removing vegetation which was encroaching on the usable areas. This complemented the poplar harvested at Site #1. This site was also very productive, however, the extreme distance from the installation site was a limiting factor. Also, the steepness of the slopes made the work very difficult. As a result, a good deal of the usable material on the upper reaches of the slope was not practical to harvest.



Harvest Sites

FIGURE 8

The crews then moved to various small sites with limited amounts of material closer to the installation site. Specific material required on site to create the proper "mix" of willow, poplar and dogwood could be harvested at these sites while better stands were being investigated. This work was less productive, with frequent moves and presented difficulty in loading onto a large transport truck. Such sites included wetlands and overgrown farm fields. Two farms were improved in this way, one to reclaim fields and another to prepare for seedling planting which occurred later in the spring.

Harvesting Site #3, Figure 8, the last large site to be harvested, was the dump road site previously mentioned. Here the combination of an abandoned railway, a hydro line, a road and some previously cleared residential properties had produced substantial regrowth of dogwood with good supplies of willow (although old) and poplar. Some alder for dead fascines was also harvested here. For the most part, the small, 2 ton, M.T.O. truck was used to transport this material to the installation site.

Material from all sites was transported no later than 24 hours after being cut to a beaver pond approximately 500m from the site to the east where it was stored for a maximum of 48 hours, with cut ends submerged in the water.

The procurement of good material in quantities properly proportioned and mixed was very difficult on this project. For the most part the sites contained a single dominant species, requiring more than one site to be active at one time. The willow, the most important species, usually occurred in random, small clumps. This necessitated frequent moves by the cutting crew and made pickup by the large truck time consuming. By the end of the project, the 2 ton truck was used almost exclusively because of its ability to respond to on-site needs.

The installation on this site began in the east corner with alternating brushlayers and live fascines. This area of the site was fairly dry and work proceeded reasonably well. The coarse nature of the soil did not present the problems with hand excavation which were originally forecast. Large rocks were reasonably rare and the soil was dry enough for convenient working, even that early in the season. The work was stopped approximately 3m from the ditch line to avoid shrubby growth in the ditch. The systems were later extended into the ditch to provide mechanical stabilization to the toe of the slope, using alder which was not expected to root and grow.

The coarse nature of the soils did, however, present some problems in backfilling to which inadequate attention was paid during construction. Although the soils were re-tamped in the installation, significant air pockets remained around much of the material, causing desiccation.

The next installation to the west was the vertical brush layers. The excavation for these was a little more difficult as they were wider and deeper, thus more and larger rocks were encountered which required moving. The soil at the base of the slope became saturated and was therefore more difficult to dig. Some frost lenses were encountered in the wet, silty portions of the slope, which further delayed the construction. Once again, backfilling was a difficult process with coarse soil particles and rocks lodging in the brushy material and not settling down to cover the branches completely. The tendency was to place material in the trench in whole bundles to speed up the installation, rather than in thin layers. During the installation it was decided to add brush layers bridging between the vertical brush layers to prevent soil movement down the slope. As these were installed late in the season, some rooted material was added to them to ensure growth.

The third installation was the brush layer/live fascine system with a central spine. The spine was excavated first, encountering similar problems to the vertical brush layers. Heavy frost was encountered along with flowing water in the lower third of the trench. Through extensive discussions, it was decided that this flow of water was not permanent but seasonal, and might be controlled by a reinforced bioengineering system. As a result, a deeper trench was excavated. The brush layers along the sides were installed and a dead fascine installed in the centre of the 'v' to intercept the major flow of water. Two live fascines were then installed above the dead fascine. Brush layers combined with live fascines were then angled into this system with the fascines penetrating and joining with the fascines of the spine.

Although this was a difficult and complicated installation, once the initial problems of water flow were resolved the work went quite smoothly. Live stakes were installed on as much of the slope as possible but the limited amount of willow suitable for the production of live stakes limited this to the bottom of the slope.

At this point, the consultants recommended stopping the installation due to the rapidly advancing season, stating that good results could not be expected after this time as the willows were now in flower. M.T.O. decided to continue for the final week to push the limits of these techniques and to try to stabilize as much of the slope as possible.

The next segment of vertical brush layers was installed, encountering much the same conditions as the first set. Brush layers with live rooted material, as previously discussed, were also added to this system.

A final test of cedar was installed, based on a suggestion by the district, using both branches inserted into the wettest soils and a whole tree laid just under the soil surface with the lower branches removed.

The entire site not covered with live stakes was then planted with high bush cranberry, rooted stock. These were also planted over the rest of the slope not covered by the bioengineering to compare the stabilizing effects of simple planting to the bioengineering work. All of the rooted dogwood cuttings were used in the hedgelayers.

The site was then cleaned up, as were those harvesting sites which required it, and the project closed. See Appendix I for production summary.

Throughout the installation the following proved to be very important:

1. Good site information is essential to avoid problems such as the "spring" encountered in the centre of the site. Although time did not permit, the advice of a geotechnical engineer would have been valuable in resolving that particular problem on site. Even better, obviously, would have been to test the site in advance so that such problems could be designed into the solution.
2. The proper mix of material dominated by willow must be addressed in planning the harvesting operation for efficiency. This has an effect on the size and number of trucks required to transport the material to the site. The smaller and more numerous the cutting sites and the more the material is segregated into pure stands, the more flexibility you must have in directing the cutting and transportation, and thus the smaller the trucks and crews required to work efficiently. With large stands of mixed, usable species, large cutting crews and trucks are most efficient. Distance is, of course, another important factor. Small trucks may not be able to move all of the material cut some distance from the installation site simply because of the travel time.

3. The successful execution of soil bioengineering requires that the excavations be opened for a minimum amount of time prior to backfilling, that material be utilized or stored in cold water within 24 hours of cutting, and that stored material be utilized within 48 hours of storage.

It is obviously difficult to meet these requirements with rigid working hours, short on-site production time, and machine schedules. Wherever possible, the foreman should be free to extend the working day or to order machines and equipment if warranted by the site conditions, weather or material availability to ensure the plants have an optimal chance of survival.

OBSERVATIONS AND DISCUSSION

Following completion of the installation, the site was first reviewed in the first week of June. At that time, the rooted material had leafed out well, giving the installation a generally healthy, green appearance. Much of the soil bioengineering work had also begun to break bud and show growth. Closer inspection showed that, in fact, the majority of the material showing the growth was willow which is normal. The dogwood showing growth was predominantly the rooted stock and no poplar showed any growth.

The site was revisited in the first week of July. Much of the willow was exhibiting vigorous growth while some of the dogwood cuttings, especially in the upper portions of the slope, were beginning to show growth. The poplar cuttings still did not exhibit any significant growth. At this time, it became apparent that the success of the installation in the wetter areas of the site and the live stakes was very good, while the drier (upper) areas of the site exhibited much less growth. The flow of water from the spine continued but it appeared to be contained in the lower fascine, and the upper live fascines were displaying good growth.

Seedlings of various plants were noticed establishing themselves in the shelter of the soil bioengineering structures. This seemed to be taking place regardless of whether the structures were growing or not. Only one area of surface erosion was noted on the site, a small rill in the last set of vertical brushlayers. This was not judged to be serious enough to warrant a repair as it was very small and had occurred during a very wet summer.

At the end of July, another review of the site was undertaken with Robbin B. Sotir of Soil Bioengineering Corporation. At that time, some of the material was excavated and examined. The plant material which was growing exhibited top growth of between 300 to 500mm for willow with 50 to 150mm root growth and top growth of 100 to 200mm for dogwood with 10 to 50mm root growth. Only a few poplar cuttings showed any growth at all. Some of the alder installed in the ditch was also found to be growing, probably because of the extremely wet conditions. Top growth averaged 50 to 150mm with root growth of 50 to 100mm. The cedar branches showed no signs of root or leaf growth but remained green.

The cuttings which did not survive were examined at random. In each case, the bark showed large dry patches where soil contact had not been maintained beneath the surface due to improper installation. Soil samples were taken which verified that conditions did not vary significantly across the site. See Appendix II.

Further evidence of seedling invasion of the soil surface of the site was noted and the rill erosion earlier noted had remained essentially the same.

The installation is considered to be successful in that the mechanical stabilization of the soil bioengineering structures has stopped the surface movement and there is sufficient growth throughout the site to ensure that the site will be covered in colonizing vegetation. The lack of soil movement and the seedling colonization seem to be reinforcing evidence of this.

At first glance, the variations of growth across the site appear to be due to moisture with the most successful areas being the wettest. We believe, however, that in fact the soils in the lower, wetter areas contain finer material. Their moist nature improved the consolidation of backfill around the cuttings, thus preventing desiccation and promoting root growth. In the upper areas, poor consolidation of the backfill around the cuttings caused the desiccation and failure. Better quality control in the installation would probably have lessened significantly the variation in quality across the site.

The near total failure of the poplar, compared to an expected 25-30% survival rate, is probably due to a lower tolerance to poor installation which occurred on this site. The dogwood exhibited a greater tolerance and willow the best. The fact that the live stakes were very successful reinforces this theory as they, of course, are not subject to backfilling. There may also be a particular variety of poplar prevalent in the area (aspen) which does not work well in soil bioengineering applications. Some additional research as to species harvested would perhaps clarify this.

The installation completed represents only about 50% of the total desired. This shortfall is probably substantially due to the crew workday length and complications in harvesting. Providing the required mixture of materials from many small, dispersed sites required a good deal of travel time and extra crew members to provide sufficient material for the installers. The frost and excess water encountered on site and the additional systems installed on site due to specific site conditions also decreased the amount of work completed within the three weeks of the project.

The installation completed during the third week, after our recommendation to end the work, has proven to be as successful as any of the previously installed soil bioengineering. Although materials were harvested from south facing slopes and the temperature reached over 22°C, the bud break and leaf growth expected did not materialize. We suspect that the more northerly species may have a greater inherent resistance to being "forced" into early growth by false springs than the more southerly species. It may also be that the experience the crew and foremen had obtained by that time resulted in a better quality of installation. In any case, the results obtained by pushing the season a week beyond the flowering stage of the willow were quite acceptable.

The lack of rooting in the cedars may simply be that they require more time to send out roots. This minimizes their usefulness for soil bioengineering, however, the installation will have to be checked next year to see if root growth has occurred and if the plants will grow. This could be useful in providing increased vegetative diversity on the site.

RECOMMENDATIONS

1. The various techniques of soil bioengineering can provide a valuable alternative technique for soil stabilization on M.T.O. sites, especially where a stable site and natural appearance is important. With careful training, a landscape crew could utilize live stakes, brushlayers, or live fascines to stabilize small failures and simple erosion, or simply to re-vegetate degraded soils. The main advantage of this would be that small problems could be fixed without expensive materials, machinery or significant disturbance to surrounding areas.

We recommend that M.T.O. introduce these three techniques to the landscape foremen in a future training session.

2. The success of this installation within Algonquin Park, with the approval of M.N.R. and without complaint from the public, proves the usefulness of soil bioengineering within the Park. The lessons learned in this installation, the experience gained by the supervisors, and the equipment in stock could be used to stabilize, much more efficiently, other areas of the slope which are eroding. This would provide an opportunity to use the techniques under normal project conditions as opposed to research conditions.

We therefore recommend that soil bioengineering be continued on the site, at the west end of the cut slope, under normal project conditions.

3. The true test of the project will be in the long term stabilization of the slope and the colonization with native species. It is important to understand the rooting characteristics of the various species and the leaf growth through time.

We therefore recommend that monitoring of the site be continued over the next three years.

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ROCK LAKE SOIL BIOENGINEERING - PRODUCTION SUMMARY

Installation Day One (Thursday, April 17, 1986)

Live Fascines	Brushlayer
13'	23'
28'	41'
50'	66'
<u>73'</u>	<u>65'</u>
164' = 54m	195' = 63m

Installation Day Two (Friday, April 18, 1986)

Live Fascines	Brushlayer	Brushlayer/Live Fascine
64'	63'	
54'	48'	34' = 11m
<u>52'</u>		(removed later)
170' = 56m	111' = 36m	

Installation Day Three and Four (Tues. & Wed., April 22 & 23, 1986)

Vertical Brushlayer	Brushlayer/Live Fascine Spine
55'	48' = 16m 55' = 18m
56'	(original 34'(11m)removed)
54'	
54'	
<u>56'</u>	
286' = 94m	

Installation Day Five (Thursday, April 24, 1986)

Vertical Brushlayer	Live Fascine	Brushlayer
	33'	29'
44' = 14m	37'	33'
	34'	30'
	32'	28'
	31'	27'
+ live stakes	33'	29'
	32'	28'
	<u>37'</u>	<u>33'</u>
	269' = 88m	237' = 78m

Installation Day Six (Friday, April 25, 1986)

Live Fachine	Live Stakes
37'	
45'	
<u>45'</u>	
127' = 42m	

clean up
pack in
trim

ROCK LAKE SOIL BIOENGINEERING - PRODUCTION SUMMARY

Installation Day Seven (Tuesday, April 29, 1986)

Vertical Brushlayers	Live Fascines(dead)	Brushlayers(dead)
71'	10'	8'
<u>72'</u>	12'	8'
	14'	6'
143' = 47m	4'	9'
	14'	8'
	<u>10'</u>	<u>7'</u>
Live Stakes	64' = 21m	46' = 15m

Installation Day Eight (Wednesday, April 30, 1986)

Vertical Brushlayers	Hedge Layers
	120'
72' = 24m	<u>40'</u>
	160' = 53m

Live Stakes
Cedar

Installation Day Nine and Ten (Thurs. & Fri. May 1, 1986)

Plant rooted stock.
Clean up ditch, construction site and pond.

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Ministry of
Agriculture
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SOIL TEST REPORT

SAMPLE RECEIVED	YEAR	MO	DAY
RESULTS REPORTED	1976	11	14

SAMPLE NO.	CROP TO BE GROWN USUALLY A CHANGE IN CROP REQUIRES A CHANGE IN FERTILIZER	FERTILIZER REQUIREMENTS †				MARKING DATE ††	SOIL TEST VALUES AND RATINGS FOR CROP SPECIFIED										TEXTURE	
		LIMESTONE TONNE/HA	NITROGEN KG/HA	PHOSPHATE KG/HA	POTASSIUM KG/HA		PHOSPHORUS		POTASSIUM		SOIL pH	BUFFER pH	MANGANESE		ZINC			C.A.
							SOIL TEST	RAT. ING	SOIL TEST	RAT. ING			SOIL TEST	RAT. ING	SOIL TEST	RAT. ING		
10	New Nursery Stock Rock Lake - 2nd Year	0	0	100	110	10	L	31	L	7.0	27	M	14	16	16	819	C	
11	New Nursery Stock Rock Lake - 2nd Year	2	2	70	120	8	L	21	L	6.0	9	L	24	23	23	53	C	
12	New Nursery Stock Rock Lake - 2nd Year	2	2	110	120	8	L	21	L	6.0	9	L	24	23	23	53	C	
13	New Nursery Stock Rock Lake - 2nd Year	0	0	60	90	13	L	71	L	6.6	65	M	15	18	18	315	C	
14	New Nursery Stock Rock Lake - 2nd Year	0	0	90	90	13	L	71	L	6.6	65	M	15	18	18	315	C	
15	New Nursery Stock Rock Lake - 2nd Year	0	0	80	120	6	L	26	L	8.1	80	M	23	15	15	3571	C	
16	New Nursery Stock Rock Lake - 2nd Year	0	0	120	120	6	L	26	L	8.1	80	M	23	15	15	3571	C	
NOTE THAT LIME IS REQUIRED ON ONE OR MORE OF YOUR FIELDS. RECOMMENDATIONS ARE BASED ON LIME WITH "AGRICULTURAL INDEX" OF 75. ASK YOUR LIME SUPPLIER FOR THE AGRICULTURAL INDEX OF HIS PRODUCT SO THAT APPLICATION RATES MAY BE ADJUSTED. DOLOMITIC LIMESTONE (HIGH IN MAGNESIUM) SHOULD BE USED TO SATISFY THE LIME REQUIREMENT ON FIELDS WITH MAGNESIUM TESTS LESS THAN 100. E (EXCESSIVE) RATINGS SIGNIFY THAT APPLICATIONS OF THIS NUTRIENT IN FERTILIZER OR MANURE MAY LOWER YIELD OR QUALITY. PHOSPHATE ADDITIONS TO SOILS WITH EXCESSIVE PHOSPHORUS LEVELS CAN INCREASE THE RISK OF WATER POLLUTION. POTASH ADDITIONS DEFICIENCY ON SOILS LOW IN ZINC AND CAN INCREASE THE RISK OF WATER POLLUTION. POTASH ADDITIONS MAY INDUCE MAGNESIUM DEFICIENCY ON SOILS LOW IN MAGNESIUM. WHEN MAGNESIUM SOIL TESTS ARE LESS THAN 20, APPLICATION OF MAGNESIUM IS RECOMMENDED FOR ALL CROPS. DOLOMITIC GROUND LIMESTONE IS THE BEST SOURCE WHERE SOIL PH IS BELOW 6.5. AT HIGHER PH VALUES APPLY 30 KG SOLUBLE MAGNESIUM PER HECTARE.																		

† 100 KG/HA = 90 LB/AC.

†† 10 TONNE/HA = 4.5 TON/AC.

†† MANURE AND SOD ADJUSTMENTS ARE EXPLAINED IN GREATER DETAIL ON BACK OF FORM.

LIQUID MANURE RATES ARE IN CUBIC METRES/HA. SOLID MANURE RATES ARE IN METRIC TONNES/HA.

IF FURTHER ASSISTANCE IS REQUIRED, CONTACT

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